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Green hydrogen production potential for developing a hydrogen economy in Pakistan

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ARTICLE INFO

Article history:

Received 8 December 2017

Received in revised form

19 January 2018

Accepted 20 January 2018

Available online xxx

Keywords:

Green hydrogen

Renewable hydrogen

Hydrogen economy

Pakistan

ABSTRACT

Pakistan's energy crisis can be diminished through the use of Renewable and alternative sources of energy. Hydrogen as an energy vector is likely to replace the fossil fuels in the future owing to the political, financial and environmental factors associated with the latter. In this regard it is imperative that conscious effort is directed towards the production of hydrogen from Renewable resources. Renewable energy resources are abundantly available in Pakistan. The need to produce Hydrogen from Renewable resources in Pakistan (or any developing economy) is investigated because it is possible to store vast amount of intermittent renewable energy for later use. Thus the introduction of Hydrogen in the energy supply chain implies the start of a Pakistan Hydrogen Economy. Many nations have developed the Hydrogen Energy Roadmap, and if Pakistan has to follow suite it is only possible through the employment of Renewable energy resources. This study estimates the potential of different Renewable resources available in Pakistan i.e. Solar, Wind, Geothermal, Biomass and Municipal Solid waste. An estimate is then made for the potential of producing hydrogen from various established technologies from each of these Renewable resources. A number of reviews have been published stating the availability and usage of Renewable energy in Pakistan; however no specific study has been focused on the use of Renewable resources for developing a Hydrogen economy or a power-to-gas system in Pakistan. This study concludes that that Biomass is the most feasible feedstock for developing a Hydrogen supply chain in Pakistan with a potential to generate 6.6 million tons of Hydrogen annually, followed by Solar PV that has a generation potential of 2.8 million tons and then Municipal solid waste with a capacity of 1 million ton per annum.

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Introduction

Energy has remained the focus of many social, political and economic debates in Pakistan. For decades the issue of energy deficiency has not been met with any solutions. Instead the problem has aggravated over the years because of population

growth and consequent spiraling demand of energy led by rapid urbanization. Thus the electrical blackouts caused by frequent load shedding have also a new partner in the form of decreased supply of natural gas, powering the majority of industrial processes as well as fulfilling the commercial, logistic and domestic cooking and heating needs. The country is

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<https://doi.org/10.1016/j.ijhydene.2018.01.113>

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Nomenclature

P2G	Power to gas
GHG	Green House Gases
PFCEV	Plug-in Fuel Cell Electric vehicles
HFCV	Hydrogen Fuel cell Vehicle
LDC	Least Developed countries
SIDS	Small Island Developing States
LLC	Land locked countries
ESMAP	Energy Sector Management Assistance Program
CSP	Concentrated Solar Power
NREL	National Renewable Energy Laboratory
USAID	United States Agency for International Development
HDR	Hot Dry Rock
EGR	Enhanced Geothermal Systems
CSP	Concentrated Solar Power
CPV	Concentrator Photovoltaic
Kgoe	Kilogram of oil equivalent
NEPRA	National Electric Power Regulatory Authority
SWG	Supercritical water gasification
MSW	Municipal Solid Waste

now faced with an even greater energy challenge than it was about a decade ago. Winter of 2015 (and onwards) have experienced massive breakdowns of both electrical and gas supply [1].

In the wake of the foreseen energy crisis, there is a need to explore all the energy resources that can be technically harnessed. Along with the need to explore newer and larger energy resources, there is also a need to generate the energy requirements that are “Climate-friendly”. This is more pronounced for Pakistan as it is one of the countries that have been hard hit by climate-change in the form of changing weather patterns, floods, drought and consequently affected agricultural output and economic growth. In this regard, Hydrogen energy that is purported to be the fuel of the future has a special role to play in the energy crisis of Pakistan and also to defray the harmful effects of GHGs that are so damaging not only for Pakistan but for the entire world. Hydrogen fuel cell technologies have matured over the years to commercial models that have potential end-use applications. The advent of Hybrid vehicles in Pakistan have initiated a new era of non-fossil fuel based applications. Similarly the power-to-gas (P2G) concept is near realization in the developed world. Correspondingly fuel-cell powered appliances have been developed that may be expensive for the time-being however are likely to approach an economical range as the technologies get less expensive with more R&D. It is very likely that H₂ fuel-cell applications will take over the existing petroleum/electrical cars as fossil fuels reach a depletion stage.

The Pakistan Energy Year book 2015 [2] represents the latest statistical data regarding energy supply (by source) and energy consumption (by sector) of the country. Table 1 presents the Primary Energy supplies by source. It can be seen that Gas and Oil remain the major contributors in Energy supplies holding 43.5% and 35.5% share respectively. Hydro

energy contributes 11% and coal has a 7% contribution. In all 86% of the energy is fossil fuel based.

Renewable energy based electricity (other than Hydro energy) has less than 1% share in the overall Energy picture. The growth rate of each individual fossil source is also observed to be rising steadily. Table 2 presents the Final Energy consumption by source, indicating an 82% share of fossil fuels.

The energy consumption in different sectors is given by Fig. 1. Industrial, Transport and Domestic sectors are the largest sectors contributing to the Energy consumption at 35%, 32% and 25% respectively.

In order to improve the energy supplies and reduce the dependence on fossil fuels and to help address the issue of climate change, Pakistan needs to expand the energy supply base with greater emphasis on Renewable energy resources. A number of studies have identified that Solar, wind and Biomass are the three major Renewable resources of Pakistan with good prospects for utilization [3] [4]. The intermittent nature and distributed availability of these Renewable energy resources implies that the harnessed energy is transformed into another form to be used later on demand. It is pertinent to mention here that the biomass resource supply in Pakistan is indeed intermittent in contrast to many other developing nations [5]. This is due to the fact that the rural population has traditionally used this resource to fulfill their immediate domestic needs for cooking and heating. Hydrogen gas [6] and “Power-to-gas” [7] technologies are two developing approaches that are being pursued globally to enable sustainability in energy supply. It is in this regard important for Pakistan that hydrogen fuel cell applications need to be considered in order to plan for a long term strategy to address the Energy security issues.

The development and arrival of commercial fuel cell automotive models have renewed the confidence in Hydrogen energy. The two automobile giants Toyota and Honda have already initiated a new era of Hydrogen powered vehicles with the launch of their commercial models namely MIRAI and CLARITY respectively [8]. Moving further, the Plug-in Fuel Cell Electric vehicles (PFCEV) have further enhanced the likelihood of an earlier transition to the Hydrogen fuel based transport sector [9]. The penetration of these vehicles in the automotive market is likely to be very low however it is expected that as technology develops and Hydrogen production becomes cheaper, these vehicles would receive a boost in production, market penetration and usage. The transport sector of Pakistan is presently 100% based on fossil fuels, however a number of hybrid vehicles (fitted with Nickel metal Hydride/Lithium Ion battery) have made very successful inroads into the Pakistani automotive market. It can thus be anticipated that as technology develops and economical applications are available off-the-shelf, its usage will grow thereby phasing out the older technology based on fossil fuels. Consequently, given the access to technology, the Hydrogen economy can play a very significant role in minimizing the use of fossil fuels in all the energy consumption sectors of Pakistan. A relevant global example pertains to the Transport sector; it has been seen that after the rapid decline of cost of batteries [10] TESLA is on its way for completion of a 5 billion battery factory to support its range of electric cars [11].

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